

# HIGH LEVEL THUNDERSTORMS OF JULY 31-AUGUST 1, 1959

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## ABSTRACT

The high level thunderstorms which occurred in Montana and northern Idaho on July 31 and August 1, 1959 resulted in critical lightning-caused fire conditions. These storms are described and the source of moisture and the instability which initiated them are discussed. It is pointed out that the reasons for the large number of lightning fires were the hot and critically dry conditions existing at the onset of these storms and the lack of any appreciable amount of precipitation with these storms rather than an excessive number of lightning strikes. The variation of the number of lightning strikes with different types of thunderstorms and the relation between the number of lightning strikes and the number of lightning-caused fires are discussed.

## 1. INTRODUCTION

Thunderstorms are usually classified as air-mass, frontal, or orographical. In some areas, especially in the mountainous areas of the West, there is the additional high-level type thunderstorm. In most cases, the separation of the storms into these categories is not clear-cut and any particular thunderstorm may be a combination of more than one type.

The high-level type thunderstorms are equally vague and difficult to fit into any simple pattern. These storms may be initiated by lifting of the upper layers by the passage of an upper cold front or a low pressure trough moving across the area. The storms may be started by the increased instability caused by the advection of cold air aloft. In some situations the air is sufficiently moist in all layers, while in other storms the air is moist and unstable only in the upper layers. In some cases, there is a rapid progression of the storms across the area. The high-level thunderstorms usually are associated with little or no precipitation reaching the ground and present a serious problem for fire control operations.

## 2. DESCRIPTION AND HISTORY OF THE STORMS

The thunderstorm period of July 31-August 1, 1959 over the Montana and northern Idaho region offers a striking example of high-level thunderstorms which can cause serious fire control problems. Figure 1 shows the area involved with the number of lightning-caused fires in each National Forest. In all, some 240 lightning-caused fires were reported at the end of the first day; during the next few days were reported an additional 100 fires which had been started by lightning strikes occurring on either July 31 or August 1.

The first signs of the storms were seen early on the morning of July 31. The radiosonde report for 1200 GMT

(0500 MST) at Boise, Idaho indicated a decided increase in moisture above the 18,000-foot level. Early morning weather reports revealed widespread altocumulus and altocumulus castellatus cloud formations with considerable virga streaming from these clouds. Aircraft observations at Missoula, Mont. indicated the base of these clouds was between 17,000 and 18,000 feet m.s.l. with an indicated cloud base temperature of  $-8^{\circ}\text{C}$ .

Thunderstorms started developing over the eastern sections of the Nezperce National Forest by 1445 MST. By 1800 MST, thunderstorms had either formed or spread over all of the Nezperce and Bitterroot National Forests, and the eastern sections of the Lolo National Forest.

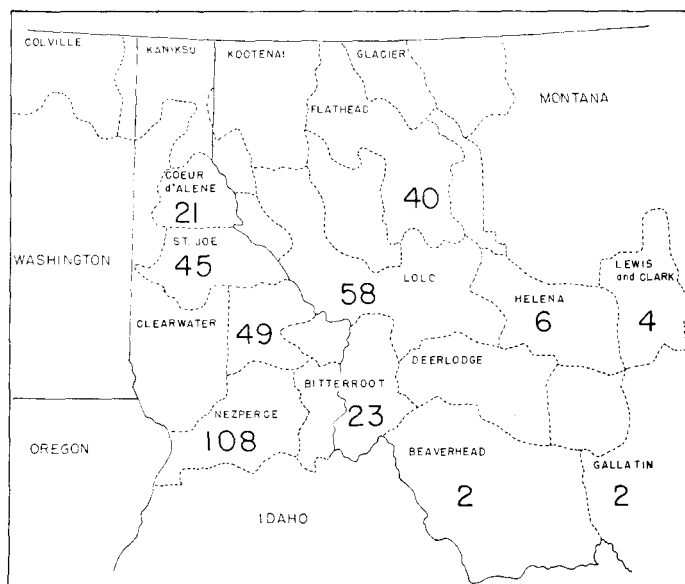


FIGURE 1.—Number of lightning-caused fires started by the July 31 and August 1, 1959 thunderstorms on each National Forest.

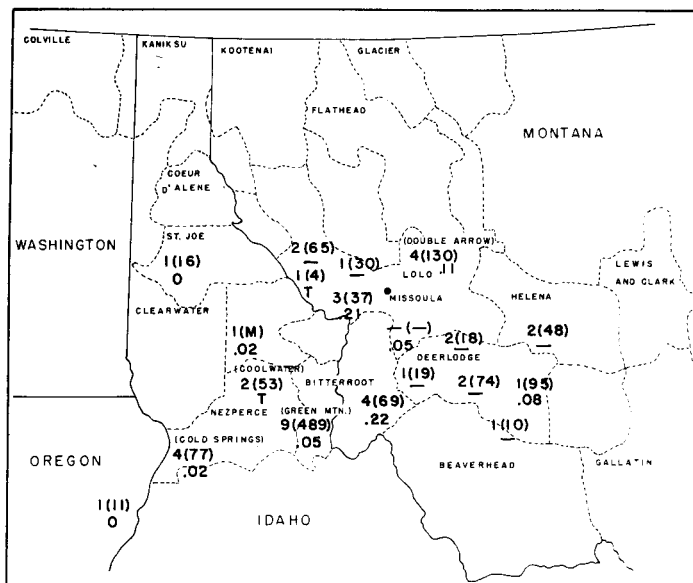


FIGURE 2.—Number of thunderstorms, total number of lightning strikes (in parentheses), and the total precipitation reported during the storm period.

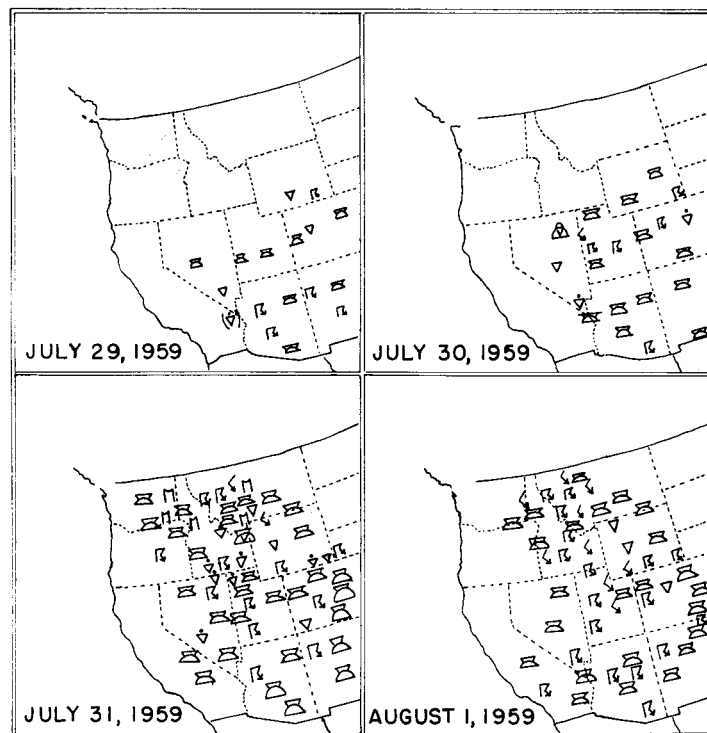


FIGURE 3.—Progression of the convective cloud activity and thunderstorms from July 29 to August 1, 1959.

Another set of thunderstorms apparently developed farther to the north over the Clearwater and St. Joe National Forests with the first storm reported at 2130 MST. These thunderstorms continued to form or spread over the northern sections of the Lolo and the southern sections of the Flathead National Forests and continued until shortly after midnight. The greatest number of lightning strikes was reported with the southern, or the earlier, set of storms.

During the early morning of August 1, a set of thunderstorms developed over the central section of the Lolo National Forest around 0400 MST with a relatively small number of lightning strikes. By daybreak there were again widespread reports of altocumulus and altocumulus castellatus cloud formations with trailing virga over the area. The 1200 GMT (0500 MST) radiosonde report for Spokane indicated considerable moisture above the 18,000-foot m.s.l. level.

Between 0700 and 0900 MST, thunderstorms had broken out all over the Nezperce, the Clearwater, and the southern sections of the Bitterroot National Forests. These storms continued to form or spread to the east-northeast extending over the central sections of the Lolo and the western sections of the Deerlodge National Forests. The greatest number of lightning strikes was reported at the Coolwater, Green Mountain, West Fork Butte, and Double Arrow Lookout Stations.

During the early afternoon, thunderstorms developed over the southern sections of the Nezperce, southern sections of the Bitterroot, southern sections of the Lolo, northern sections of the Beaverhead, and the Helena National Forests. The greatest number of lightning strikes was reported at the Cold Springs and Green Moun-

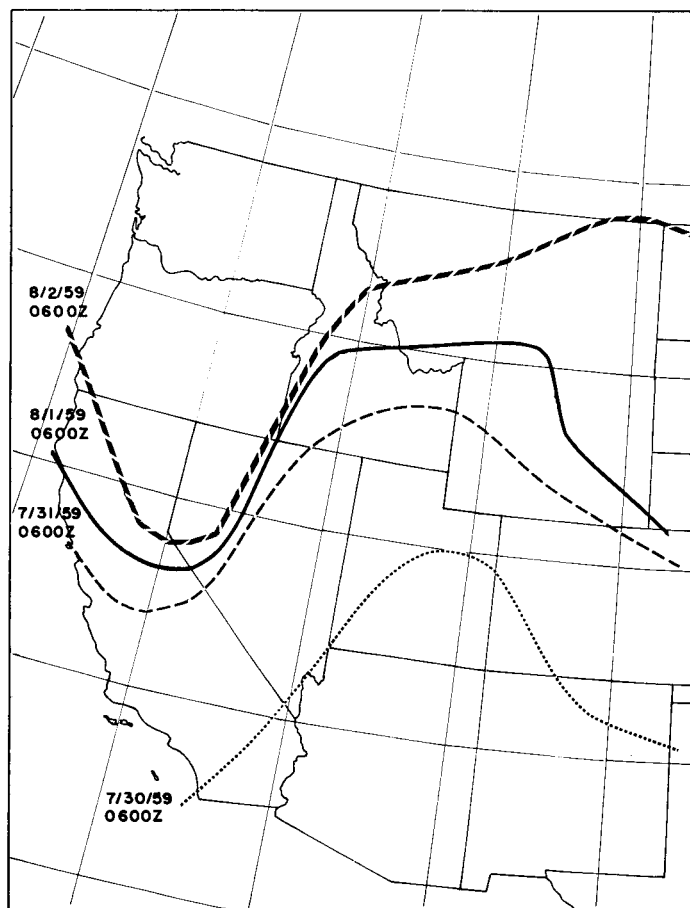


FIGURE 4.—Progression of the 50° F. surface dew points northward during the storm period.



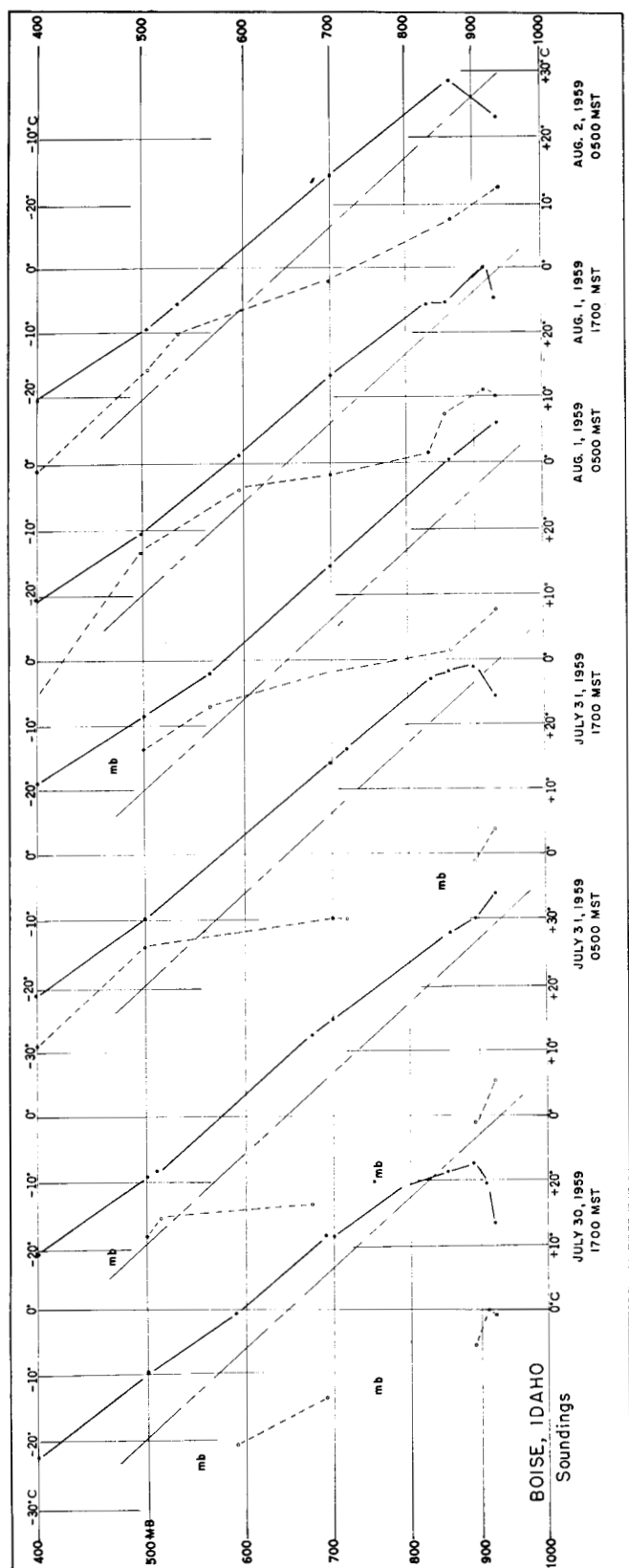


FIGURE 7.—Sequence of radiosonde reports for Boise, Idaho during the storm period.

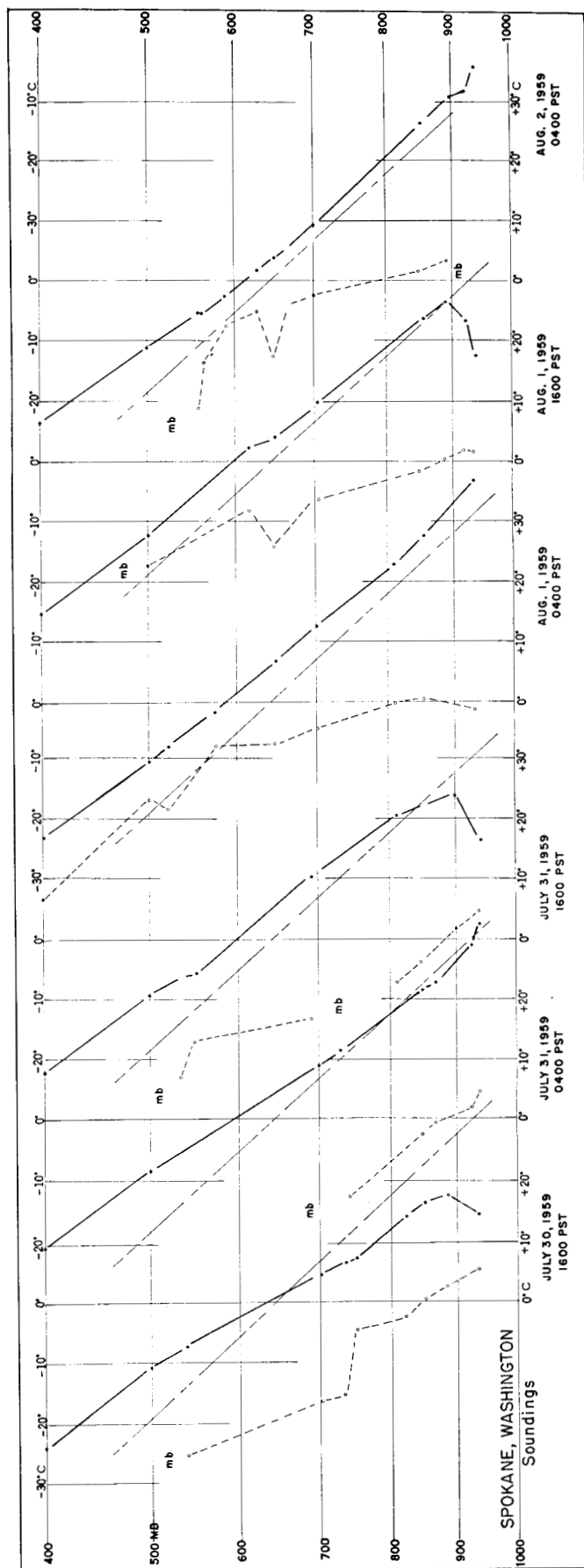


FIGURE 8.—Sequence of radiosonde reports for Spokane, Wash. during the storm period.

Many other high level thunderstorms have been associated with the deepening of an intense cold low pressure area off the northwestern coast or the passage of an upper cold front or low pressure trough which could be easily traced on the 500-mb. charts. In this case the 500-mb. charts (fig. 5) show no such progression. The 24-hour pressure-height changes showed general increases over the West up to the afternoon of July 31 (0000 GMT August 1) except for the decreases which set in at Winnemucca, Nev. and Salt Lake City, Utah. Between this time and late afternoon August 1 (0000 GMT August 2) there were decided decreases over the entire area. Similar results occurred at the 700-mb. level but are not shown.

A study of the initial vertical motion chart (fig. 6) for 0000 GMT August 1 shows widespread upward vertical motion over the Montana-Idaho area on the afternoon of July 31. On the previous day, there had been either no marked upward vertical motion or slight downward currents over this area southward.

The change in the vertical motion and stability patterns can be seen in the radiosonde reports for Boise and Spokane (figs. 7 and 8). There is some evidence of subsidence in the upper levels through the early morning of July 31 which is in agreement with the increasing pressure-heights on the 500-mb. charts for this period.

Increasing moisture and instability is apparent in the upper levels in the afternoon sounding of July 31 at Boise and the early morning sounding of August 1 at Spokane. This agrees with the upward vertical motions and decreases in the 500-mb. pressure-heights. The late afternoon sounding for August 1 at Spokane shows the return of subsidence and drier air in the upper levels.

In spite of the slight increase in the surface moisture, as was shown in the northward spread of the 50° F. dew point, there was a lack of sufficient moisture and instability in the lower levels to initiate the thunderstorms. It is apparent that these thunderstorms can only be explained on the basis of the increase in moisture and instability in the upper levels. On the basis of the early morning radiosonde and the cloud data on July 31, thunderstorms were forecast for late afternoon and evening. On the morning of August 1, thunderstorms were forecast to continue throughout the day and evening with decreased activity on August 2.

#### 4. RELATION OF LIGHTNING STRIKES AND LIGHTNING-CAUSED FIRES

The question arises as to why this thunderstorm period produced so many lightning fires. There are several interesting aspects to this question. While these cannot all be considered in this paper, perhaps some insight can be gained on the subject.

The weather conditions had been such that the surface fuels were very dry at the onset of these thunderstorms. The entire month of July had been very dry and the temperatures were quite hot near the end of the month. The total precipitation was only 0.13 in Missoula up to July 31.

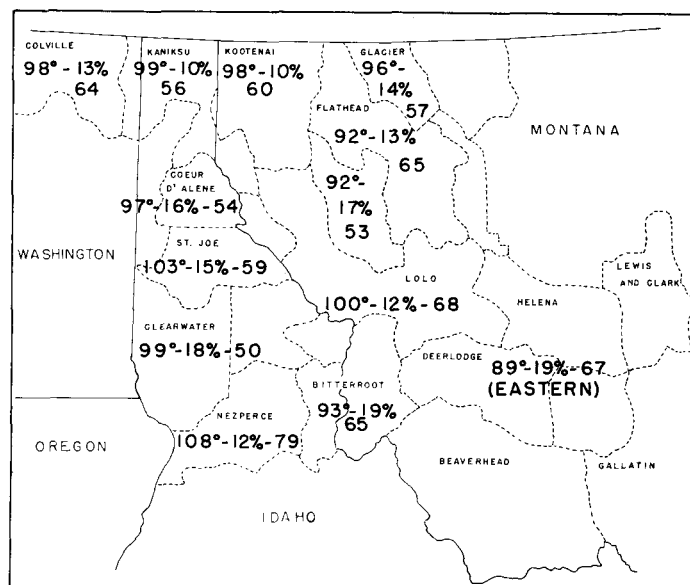


FIGURE 9.—Maximum surface temperatures (°F.), minimum relative humidities (percent) and the highest burning indices on each National Forest on the afternoon of July 31, 1959.

The only lightning at Missoula had been reported on July 3. This low precipitation and thunderstorm activity was quite general over the entire region. For the 23 days from July 8 to July 30, there had been only 18 National Forest-thunderstorm days on the 10 western forests and 26 on the 5 eastern forests. Project Skyfire lookout stations reported only 25 percent of the normal number of thunderstorms and 16 percent of the normal number of lightning strikes.

The main reason for this lack of precipitation and thunderstorms was the existence of a persistent and strong high pressure ridge circulation at the upper levels (700, 500, and 250 mb.) [2]. The influence of the deep cold low pressure area which is usually present off the northwestern coast was significantly weak during July. Only a few minor troughs moved eastward and they were confined north of the Canadian border and did not affect the Montana area. What little storm activity did occur was mostly isolated and scattered.

The conditions at the onset of the storm period were hot and dry. As can be seen in figure 9, the maximum surface temperatures were in the upper 90's or lower 100's and the minimum relative humidities ranged from 10 to 20 percent. The fire-danger rating, or burning index, based on current fuel moisture reading, the 5-day total fuel moisture reading, the wind speed, and the relative humidity, had been building up during the last part of July. At the onset of this storm period, the maximum burning index ranged from 50 to 70.

In the comparison of this thunderstorm period with other high-level storms, the radiosonde data are highly significant. The storms of July 1-8, 1955 and July 7-8, 1959 were initiated by the advection of cold air aloft or the passage of a low pressure trough aloft. But the

TABLE 1.—Comparison of total number of lightning strikes with type of storm. (Strikes per day for 25 days of greatest frequency of strikes in 5-year period, in descending order.)

Date	Total number of strikes	Type of storm
7-18-56	1262	Air mass
7-16-55	1088	Frontal zone
7-13-56	1067	Cold front
7-13-57	1045	Cold front
7-20-56	853	Air mass
7-9-56	755	Air mass
7-28-58	749	Air mass
7-17-58	739	Air mass
7-11-56	720	Air mass
7-31-56	714	Cold front
8-1-59	694	Upper-level
7-17-55	668	Cold front
7-9-55	657	Frontal zone
7-25-55	558	Cold low aloft
7-28-58	509	Air mass
7-19-57	504	Air mass
7-23-55	492	Air mass
7-18-58	489	Air mass and weak low aloft
8-9-56	448	Cold front
7-21-55	442	Air mass
7-21-57	412	Low pressure trough aloft
7-22-55	409	Cold low aloft
7-12-56	380	Air mass
8-6-56	370	Low pressure trough aloft
7-15-55	364	Frontal zone

radiosonde observations indicated that the air was quite moist at all levels and the resulting precipitation was generally heavy. The conditions for the July 31–August 1, 1959 storm period indicated that sufficient moisture and instability to initiate thunderstorms occurred in the upper levels only. This was similar to the storm period of August 24–25, 1955 which also produced little precipitation.

With the base of the clouds and storms quite high and the air very dry below the clouds, most of the precipitation appeared as virga and little reached the ground.

The question arises whether these high-level storms produce an excessive number of lightning strikes. Some data have been gathered on this problem during the past 5 years of Project Skyfire operations. Table 1 gives the tabulation of the total number of cloud-to-ground lightning strikes for the 25 days with the greatest number of strikes along with the classification of the thunderstorms on those days. While it is difficult to be completely certain of the above classification, it appears that more strikes occurred on the days with air-mass and frontal types of thunderstorms than with the high-level type thunderstorms. This would indicate that one would not expect to find more strikes on the days with high-level thunderstorms. There were only 262 lightning strikes reported on July 31 and 694 on August 1.

In the scatter diagram shown in figure 10, the number of lightning strikes is plotted against two variables: the averages of the 0000 GMT Boise and Spokane stability indices (Showalter) and the total precipitable water computed from the 0000 GMT Boise and Spokane radiosonde data. The number of lightning strikes, as well as the chance of thunderstorm occurrence, seems to be strongly dependent on these two variables. While there is considerable scatter, it is possible to separate the lightning strike data into classes with both the average total number of lightning strikes and the chance of

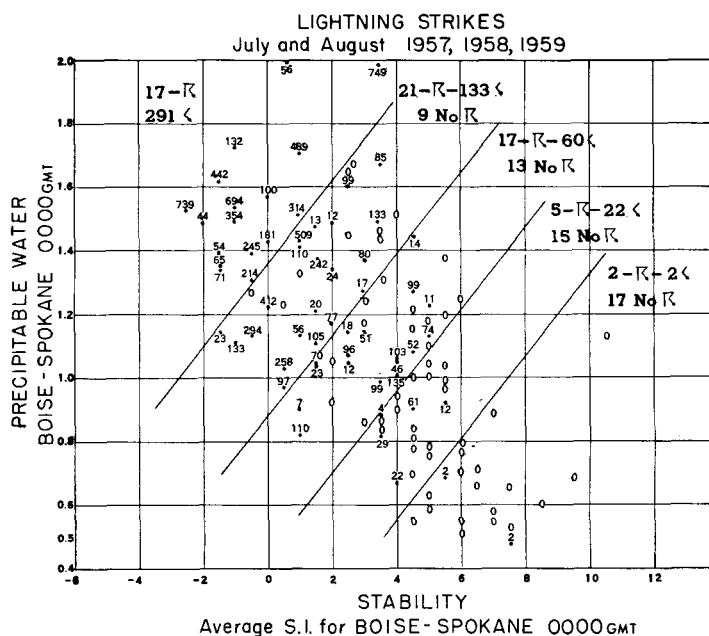


FIGURE 10.—Number of lightning strikes over the region plotted against the two variables: total precipitable water (gm.) from the 0000 GMT Boise and Spokane soundings and the average stability index (S.I.) from the 0000 GMT Boise and Spokane soundings. Data are separated into 5 classes with increasing chance of thunderstorm occurrence and average total number of lightning strikes.

thunderstorm occurrence increasing toward the corner of the chart with the greater instability and higher precipitable water content.

The high-level type thunderstorm with the moisture and instability restricted to the upper levels can not be expected to appear near the corner of the scatter diagram with high overall precipitable water and instability index. Therefore, these high-level storms would not be expected to show as great a number of lightning strikes. It has also been speculated that more strikes should be associated with the storms with the greatest vertical development. The high-level storms with relatively small vertical development should not be expected to have so many lightning strikes.

It can be concluded that the large number of lightning fires set off during this storm period was due to the extremely hot and critically dry conditions at the surface at the onset of these storms and to the lack of any appreciable amount of precipitation during these storms, rather than to any excessive number of actual cloud-to-ground lightning strikes.

In addition to the type of surface fuel, the dryness of the fuels, and the amount of precipitation associated with the lightning strikes, another important factor in the efficiency of lightning strikes in producing fires is the amount of current carried by the strikes and the duration of the strikes. Norinder [3] refers to the strikes with unusually heavy current and of long duration as

'gangster' type strikes. These strikes should have a greater fire-starting potential. Much more research is needed along these lines.

### 5. CONCLUSIONS

As a result of this study, it is suggested that the term high-level type thunderstorm be restricted to the situations where sufficient moisture and instability for thunderstorm initiation are to be found in the upper levels only. The actual triggering action may be the advection of cold air aloft, the passage of an upper cold front or low pressure trough, or as in this case, widespread upward vertical motion. The actual speed of motion of these storms may vary considerably, ranging from nearly stagnant conditions to rapidly progressing systems. These storms are all associated with high cloud bases and with little or no precipitation reaching the ground.

Other storm situations with moist conditions at all levels, even though they may be initiated by the advection of cold air aloft or the passage of an upper low pressure system, have much lower cloud bases and are associated

with considerable precipitation; they should be classed along with the other air-mass or frontal types of storm.

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